Characterization of 808 nm Quasi-constant Wave Laser Diode Arrays

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Abstract – High-power laser diode arrays are used for a variety of space-based laser programs as an energy source for diode-pumped solid-state lasers. Specifically, 1064 nm Nd:YAG lasers require laser diode arrays emitting at a wavelength of 808 nm that operate at quasi-cw peak powers of 100 Watts per bar. Reliability and performance data is needed for these components; particularly for operation in a satellite environment. To plan future laser missions, it is important to better understand these components and the effect of various environmental and operational conditions, which the laser diode arrays (LDAs) are likely to encounter. This will enable educated design trades, which are necessary to properly scope new laser instruments.

This research is developing diagnostic tools, quantifying the performance of available products, and using data gathered to enable the improvement of product performance. We present measurements of LDA optical power, near field images, emission spectrum, micro-photoluminescence spectrum, high-power microscope images and infrared images. We also present plans for future research. *

I. INTRODUCTION

Lasers show substantial promise for a wide variety of satellite instruments, enabling new and rewarding remote sensing capabilities. Q-switched, 1064 nm, Nd:YAG lasers have been the leading satellite laser technology. They have been flown on NASA missions including MOLA [1] and GLAS [2] and have been proposed and funded for missions like CALIPSO, VCL and MLA. Q-switched Nd:YAG lasers offer short, (~10 ns) high-energy laser pulses, which are excellent for ranging applications. Despite the increasing use and acceptance of these devices, there remain technological hurdles, which must be overcome for these lasers to reach their full potential.

One challenge, which remains, is the laser diode arrays (LDAs). Q-switched Nd:YAG lasers are most efficient when optically pumped by diode arrays emitting at a wavelength of 808 nm and operating at quasi-constant wave (QCW) peak powers of 100 Watts (or more). The LDAs, the energy source for the Nd:YAG lasers, are an integral component and a potential failure mechanism of the instrument.

Given the crucial role of the LDAs in these laser instruments, it is imperative that they be well understood and their performance quantified. Reliability and performance data for these components, particularly when operated in a satellite environment, is very limited [3, 4]. To plan future laser missions and make educated design trades, it is important to get a better understanding of these components and the effect of various environmental and operational conditions, which the LDAs are likely to encounter.

Our global objective is to facilitate the successful application of QCW LDAs in NASA missions. To this end, we need to better understand the device strengths and limitations. This research is designed to quantify the performance of LDAs and to discover the best techniques and strategies to apply this technology for maximum effect and minimum risk.

We first need to quantify a base level of performance for the device and answer the following questions. How long will LDAs last (under a canonical set of conditions)? What is the performance level and degradation rate? How much variance is there between similar devices operated the same way. How does the performance change when the operational and environmental conditions change? To what

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degree can the performance and reliability be predicted from initial characterization? What parameters are important in this prediction? Can we understand the physics of device limitations and improve performance?

To address these issues, we employ a strategy to compile comprehensive data sets throughout the device life cycle. We first fully characterize the LDAs to establish a baseline for individual array performance and status. Then the diodes will be subjected to a form of stress like running them in a defined life test, subjecting them to radiation or some other prescribed test. The LDAs will then be characterized again to observe the effect of the stressor. This procedure will be repeated many times for different stressors on many diodes. In this way, we intend to see the effect different operational and environmental conditions have on the LDAs. This will enable a set of recommended practices for operation and handling of the diodes to maximize performance and mitigate risk. We will also try to correlate the observed performance over time with the initial observed parameters to formulate a screening criterion, which can be used to predict device performance. This will eventually be used to judge the flight readiness of particular devices.

Substantial attention has been given to creating a repeatable characterization so observed changes are attributed to stress parameter rather than measurement variability.

In this paper we present the measurements and techniques we are employing to characterize the 808 nm QCW LDAs.

I. LDA CHARACTERIZATION

In this section we discuss the procedures and measurements used to characterize the LDA. All measurements are carried out on a laminar flow bench that controls the particle count of the environment seen by the LDAs. The work area is electrostatic discharge (ESD) controlled to minimize risk of damage to LDAs. Temperature, and humidity are monitored.

All LDAs are initially put on a mounting plate with electrical and mechanical interfaces that connect to all other test hardware. This is designed to minimize risk of failure due to unnecessary handling. Clear written procedures for all functions and measurements ensure repeatability and traceability.

After mounting LDA on the mounting plate, a complete microscopic facet inspection is completed saving an array of digital photos of the LDA facets. The Photos are 200X magnification. An example is illustrated in Fig. 1. This visual inspection is done before we apply any current so we can be certain that this inspection represents the initial condition of the facet.

We then place the LDA (with mounting plate) in a test fixture designed for performance characterization. The diode mounting plate is thermally controlled to stay at 25 °C for all the following measurements. We measure the average optical power of the entire array with an integrating sphere and power meter as a function of drive current. An example of this measurement is demonstrated in Fig. 2. We also measure all the electrical drive parameters. We measure time resolved voltage, resistance, current and efficiency.

While the laser is powered on, we take a digital image of the near field of the LDA emission to quantify the spatial distribution of the optical power. From this data we will be able to monitor the output of the individual emitters in the array. An example of one of these images is shown in Fig. 3.

We measure the average emission spectrum of the LDAs at an operational current of 100A. An example of the spectral measurement is shown in Fig. 4

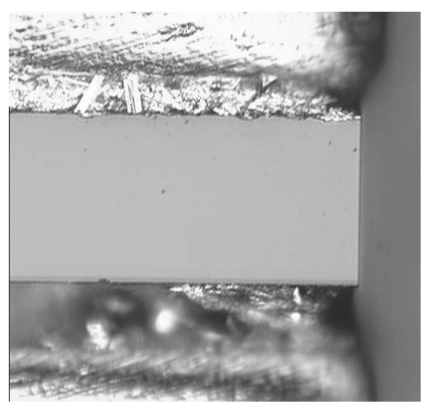


Fig. 1. High power (200X) microscope image of laser diode array facet.

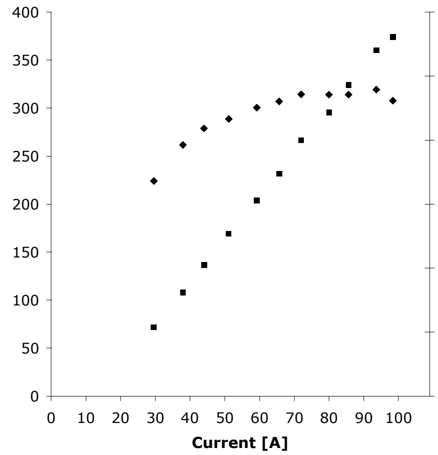


Fig. 2. Optical power (watts) vs. Current (amps) of a 4-bar laser diode array.

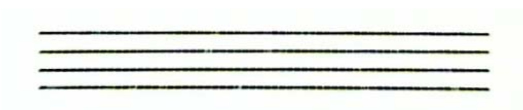


Fig. 3. Near field image of an operating 4-bar laser diode array.

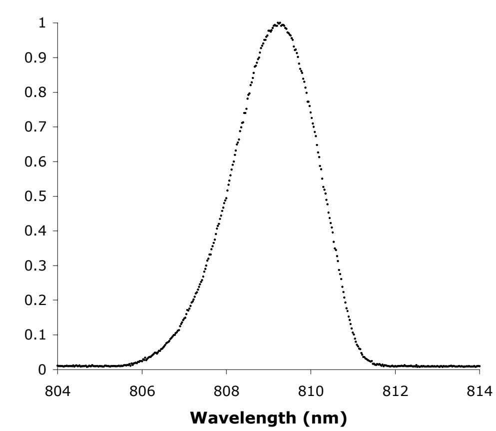
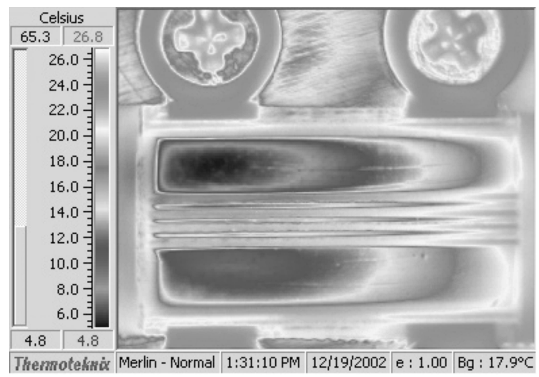


Fig. 4. Optical emission spectrum of a laser diode array in quasi-cw operation of 100 watts/bar.

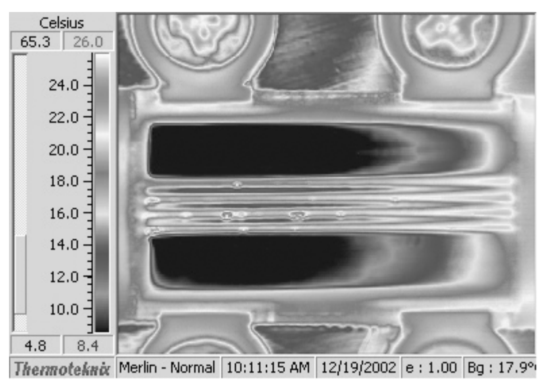
We record Infrared images of the LDA to show temperature profile of the device. This can illustrate hot spots as illustrated in Fig. 5 (b). The gradient from left to right is a result of a slight lack of focus. Hot spots can clearly be observed in the image of the operating LDA. The presence of the hot spots may indicate potentially bad regions of the diode bar. This measurement, using a 1x lens system, has a spatial resolution of 30 microns and a temperature resolution of 20 mK. We also have the capability to use a 4x lens system with a spatial resolution of ~10 microns.

We have also measured the micro-photoluminescence spectrum of the LDA. This is done using a microscope, which directs the 532 nm excitation light to the focus of the optical system. Monitoring the photoluminescence spectrum enables us to track changes in the mechanical stress and other parameters. [5 - 10]

The combination of these measurements analyzed together shows promise to yield a more complete picture of the LDA and its life cycle.



(a)



(b)

Fig. 5. Infrared image of, (a) a non-operating and (b) an operating 4-bar laser diode array demonstrating hot areas in facet region during operation.

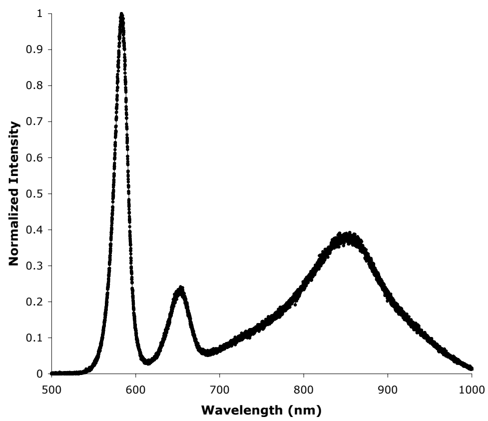


Fig. 6. Micro-photoluminescence spectrum of laser diode array.

III. Future work

In addition to the measurements demonstrated above, we are also working to implement several other characterization techniques. Many of the measurements can be improved by spatially and temporally resolving them. For instance, measuring the emission spectrum of an individual emitter as opposed to the average of all the emitters. In this way, a more detailed view of the device is attainable. Similarly many of the measurements can be temporally resolved to illustrate the dynamics within a single pulse as compared with a temporal average which blurs the on and off cycles. Improving these measurements should provide further insight into the nature of these devices.

IV. Conclusion

There is a dearth of information on the how QCW LDAs operate over long duration, hands-off operation in a space environment. There are many variables that can affect the reliability and performance. This research is one step in a systematic approach to understanding the fundamental issues of operating these devices effectively.

As the time between proposal and launch decreases and there is a push to fly more technologically advanced instruments, being armed with the necessary information at the earliest stage is crucial. More information is required up front to properly scope new mission concepts. This research should allow more accurate, reliable and knowledgeable mission concepts and designs.

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References

[1] D.E. Smith et al, “Mars Orbiter Laser Altimeter: experiment summary after the first year of global mapping of Mars,” J. Geophysical Research-Planets, Vol. 106 (E10): pp. 23689-23722 October 2001.

[2] H.J. Zwally et al, “ICESat's laser measurements of polar ice, atmosphere, ocean, and land,” J Geodynamics, Vol. 34 (3-4): pp. 405-445 October-November 2002

[3] N.W. Carlson, *Monolithic diode-laser arrays*, Berlin: Springer-Verlag, 1994

[4] M. A. Stephen, M. A. Krainak, and J. L. Dallas, “Quasi-CW Laser Diode Bar Life Tests,” *Laser-induced Damage in Optical Materials: 1997*, SPIE Vol. 3244 (1997).

[5] S. Perkowitz, “Optical characterization of semiconductors: infrared, raman and photoluminescence spectroscopy, Academic Press, New York, 1993.

[6] L. Pavesi, M. Guzzi, J. Appl. Phys. 75 (1994) 4779.

[7] H.B. Bebb, E.W. Williams, in: R.K. Williardson, A.C. Beer (Eds.), Semiconductors and Semimetals, vol. 8, Academic Press, New York, 1972, p. 181.

[8] J.I. Pankove, Optical Processes in Semiconductors, Dover, New York, 1975.

[9] A.H. Kitai (Ed.), Solid State Luminescence, Chapman and Hall, Cambridge, 1993.

[10] Jean-Pierre Landesman, Materials Science and Engineering B91–92 (2002) 55–61